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MAGNETIC WORK OF THE DOMINION OBSERVATORY

R. GLENN MADILL

Research into the hidden mysteries of Nature and of Science began shortly after Father Adam—expelled from a life of luxury and ease—began to work for a living. Previous to that time research seems to have been carried on only in the realms of botany and zoology. Nothing was known at that time about the science of Terrestrial Magnetism and not even at a later date when Noah, commander of the *Ark*, made his memorable voyage. Had he been in possession of a mariner's compass history might have been written differently.

However, early in the history of civilization, a certain stone was found that possessed the remarkable power of attracting iron. It is not known how this discovery was made. The shepherds while tending their flocks may have noticed this substance, since they examined both celestial and terrestrial objects with minute care. Or possibly the early miners, whilst delving into the earth in an endeavour to read its secrets, made the find. This subject is purely one of conjecture and it is sufficient to say that the discovery was made.

Various names were given to this stone, but the names that stuck are lodestone and magnet. The name magnet was derived, probably, from the place where it was procured, in Magnesia, in Asia Minor.

It appears to have taken the ancients a long time to come to a

complete knowledge of the properties of the lodestone. That it attracted small pieces of iron and that it could transmit that power to the metal was known to the Greeks toward the end of the seventh century B.C. It took the Greeks fifteen centuries to find out that when a piece of lodestone was suspended in a suitable manner, it would come to rest in a definite position, and that it possessed poles of opposite character.

The Chinese and the Japanese had a much earlier knowledge of the directive property of the lodestone, in fact it has been stated that this knowledge extends back to 2634 B.C. There are references, however, in the ancient records of these people, to a so-called south-pointing cart, probably used as early as 1110 B.C. The south pointing cart had mounted in front a pivoted figure with an outstretched arm. A magnet was so placed in this figure that the arm would always point south. This device was replaced by a compass using a floating needle, which compass was simply a bowl of water on the surface of which was a magnetized needle supported by a float.

The earliest definite mention of the use of the compass in Europe occurs in a treatise written about the end of the 12th century by a monk, Alexander of Neckam.

In 1296, Petrus Peregrinus wrote a treatise on the magnet. In this work he described improvements to the compass by the substitution of a pivoted needle for the one floating on water and by the graduation of the rim of the circular bowl.

Italians have claimed that Flavio Gioja, of Amalfi, Italy, invented the mariner's compass about the year 1302. There seems to be some doubt as to the authenticity of this claim, but it is probable that Gioja should be credited with improving the compass by the addition of the compass card attached to and moving with the needle.

The mariner's compass was in general use at the end of the 14th century, and as a result trade expanded and an impetus was given to exploration. Instead of following the shore and being unable to travel when fog or mist obscured the sun by day and the stars by night, the mariner could sail boldly out of sight of land and could keep on his course regardless of most weather conditions.

Columbus, during his voyage to the New World in 1492, discovered that the compass needle does not in general point true north. This discovery of the variation, or declination, of the magnetic needle—which is the angular distance between true north and magnetic north as shown by the needle—was of profound importance in the study of the earth's magnetism. This magnetic declination was first observed on land at Rome in the year 1510.

Although it had been noticed that the north end of the compass needle tended to dip below the horizon in northern latitudes, it was left for Robert Norman, of London, to devise an apparatus with a magnetized needle supported by a horizontal axis and measure the amount of dip. This is described in his book published in 1581. Magnetic dip or inclination, which is the angular distance between the magnetic needle and the horizontal plane when thus suspended was a discovery of great importance.

We find at this time a state of affairs which to us seems to be remarkable. Notwithstanding the fact that the mariner's compass had been in use in some form or other for centuries, and in spite of the fact that magnetic declination and dip were known, no one had inquired into the cause of the phenomena. It was believed that the compass needle pointed to either the pole star, or some pole of the heavens. The whole subject was wrapped up in mystery. The cloud of superstition and the veil of ignorance that surrounded the lodestone never had been dispelled. No one seems to have asked the inevitable question, "Why?"

The science of Terrestrial Magnetism began in the year 1600 when Gilbert published his memorable book *De Magnete*. In this book Gilbert advanced the theory that the earth itself is a great magnet. He was the first to grasp the essential idea that the earth has magnetic properties and acts as a huge spherical magnet, and that all magnets on its surface are influenced by its magnetic force and direct their poles to the magnetic poles of the earth. Gilbert's book dispelled the idea that the directive power of the compass was due to some celestial attraction and directed attention to the magnetic properties of the earth itself.

The next discovery to be made was that the magnetic declination changed with time. This was announced by Gellibrand in

1634. From observations taken at Deptford, near London Bridge, he found that the magnetic declination had changed by about 7° between 1580 and 1634. Since that time it has been discovered that the dip and the intensity of the earth's magnetism change in a similar manner.

Now it had always been believed that the declination, although it changed from place to place, was a fixed quantity at any one position. Great consternation arose when the discovery was announced that this was not the case. The mariner could no longer depend on the value of the declination at distant ports, especially if the observations had been taken some time previous to his visit. The land surveyors, who had been using the compass to define boundaries, could not retrace old lines without first ascertaining the change in the magnetic declination since the original survey was made.

Since the compass was essential to navigation and to the expansion of trade, it was deemed advisable to construct charts of the ocean areas so that mariners could be informed as to the declination at various places. This work was begun by Halley with the ship *Paramour Pink* at the expense of the British Government. A chart was published in 1701 giving the lines of equal magnetic declination over the Atlantic Ocean from observations taken by Halley between the years 1698 and 1701. This work has been carried on ever since and charts are published frequently giving the lines of equal declination, dip, and horizontal intensity.

The fact that the magnetic declination varied throughout the day was announced by Graham of London in 1722.

Data thus far obtained related only to the direction of the earth's magnetic force. The intensity of the earth's magnetism was first mentioned in 1769 when relative values of horizontal intensity were obtained and relative values of vertical intensity in 1776.

The mathematical discussion of the problem of the earth's magnetism was instituted by Gauss in 1838. It was evident that sufficient data had not been obtained from the earth as a whole for much headway to be made with the problem. It was found that a complete magnetic survey of the globe was an imperative

necessity and also the establishment of magnetic observatories in various places to record the magnetic changes and to measure the magnetic elements, the declination, dip, and horizontal intensity.

Great Britain set an example to other nations by making a magnetic survey of the British Isles between 1836 and 1838, which work was extended to her colonies. Soon after 1840 magnetic observatories were established in widely separated parts to secure simultaneous data regarding the earth's magnetism.

The development of the science of Terrestrial Magnetism in Canada closely parallels the development of the country. Magnetic observations were made at Halifax by Champlain in 1604. Observations at Quebec date back to 1642 and at Montreal to 1700. Owing to the voyages of the Hudson Bay Company into Hudson bay, magnetic observations were taken as early as 1668 at Fort Albany and in 1725 at York Factory. Captain Cook observed at Nootka, Vancouver island, in 1778. From 1819 to 1826 Sir John Franklin made numerous magnetic observations on his widely distributed explorations.

The Toronto Magnetic Observatory began operations in September 1840. This observatory has been in continuous operation ever since, and it is, and has been, one of the principal magnetic stations of the world. In 1898, owing to the disturbances due to electric cars in Toronto, the instruments were moved to Agincourt, 12 miles from the original station, where they are in operation at present. An observatory was established in Meanook, Alberta, in 1916, this observatory being under the direction of the Toronto office. The Toronto Magnetic Observatory is operated by the Meteorological Service of Canada, which is a branch of the Department of Marine and Fisheries.

In 1843-46, Sir John Lefroy, under the auspices of the Royal Society, made an extensive magnetic survey of Western Canada following the Hudson Bay Company's trade routes.

A magnetic observatory was established at Fort Rae in 1882 and continued in operation for one year. Fort Rae was one of the circumpolar positions occupied in accordance with the scheme proposed by Lieut. Weyprecht for concerted physical observations

FIG. 1. STOPPING FOR LUNCH.

On the west coast of Hudson bay, near Port Nelson, the water is generally quite shallow. The distance from the position of the canoe to shore is approximately one mile.

to be carried on for at least one full year at different stations situated around the poles.

In 1880, the Topographical Survey Branch of the Department of the Interior—at that time operating chiefly in Western Canada and now over the entire Dominion—began to gather magnetic information. The determination of the magnetic elements was merely an adjunct to the regular survey work and did not always possess the degree of accuracy desired for a discussion of the problem of the earth's magnetism, so the Carnegie Institution of Washington

FIG. 2. TRANSPORTATION ON HUDSON BAY RAILWAY.
Railway motor lorry on which the magnetic survey party made the trip from The Pas, Man., to the end of steel, a distance of approximately 330 miles.

began sending magnetic survey parties into Canada in 1905. In 1907 the Dominion Observatory recognized the importance of this work and began a systematic scientific survey of Canada with instruments of the approved design. In 1913 the Carnegie Institution withdrew its parties from this country, convinced that the Canadian observers were in a position to obtain information with the degree of accuracy required.

The Meteorological Service of Canada, in addition to maintaining the standard magnetic instruments, has conducted several

FIG. 3. MAGNETIC STATION, YORK FACTORY, MAN.

The site of the magnetic station is indicated roughly by the location of the tent in the foreground. The buildings are part of those comprising the post of the Hudson Bay Company at York Factory.

important scientific magnetic surveys, including a survey of Mackenzie river in 1910, a survey in subpolar regions in 1908-1909, and a survey of Hudson strait and Hudson bay in 1912.

Since 1907 the Dominion Observatory has occupied 984 stations, representing 643 distinct localities. Many of these stations—183 in number—are termed repeat stations and are reoccupied at intervals of approximately five years, for the purpose of keeping a check on the changes that take place in the values of the magnetic elements throughout the years. A table is appended showing the geographical distribution of the Dominion Observatory magnetic stations. A summary of magnetic results obtained in the years 1921-22-23 appears at the end of this article.

Observations have been taken from the coast of Labrador to the coast of British Columbia, and from the Canada-United States boundary to the International Boundary on Yukon river, to the mouth of the Mackenzie, to Nueltin lake in the barren lands of the Northwest Territories, to north of Churchill on Hudson bay, and to Nain on the Labrador coast.

The task of covering Canada with a network of magnetic stations is a huge one. This can be readily understood since the greater part of the country lies to the north of the railway belt. Data from the far north can be obtained only by dint of hard work and by means of primitive methods of transportation. The observer becomes in fact an Indian and as such he must suffer many and diverse discomforts and hardships in travel. He must be prepared to read the secrets of Nature, to be amused at the vicissitudes of rapids and muskeg portages, to smile in the face of storms, and to laugh when he needs must subsist on anything or nothing as the case may be, and especially when his life's blood is being slowly drained by hordes of black flies and mosquitoes.

The seasons of 1922 and 1923 were devoted to the securing of magnetic data from Northern Canada. One observer worked along the Peace, the Athabaska, the Slave, and Mackenzie rivers, reaching Aklavik in the Mackenzie delta. The other observer worked in northern Manitoba and northern Saskatchewan, covering the territory between the Saskatchewan-Manitoba boundary and the west coast of Hudson bay, and between The Pas and the 60th parallel.

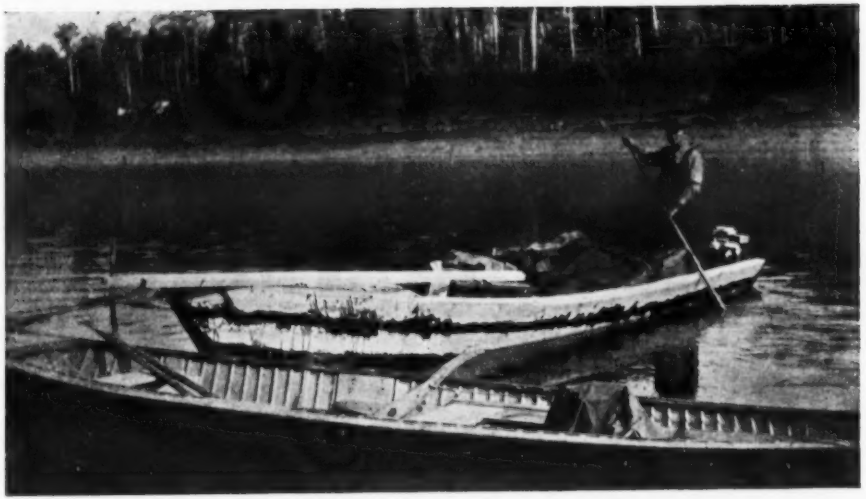


FIG. 4. LOOKING ACROSS CLEARWATER RIVER.

The craft, locally known as a skiff, is equipped with an outboard motor, in which the magnetic survey party made the trip from McMurray to Fitzgerald. Smith portage was then crossed by wagon and Slave river and Great Slave lake by steamer, after which the journey was resumed in the skiff down Mackenzie river to Aklavik, a distance of about 1,000 miles.

FIG. 5. SHOOTING RAPIDS ON KISSISSING RIVER.

One of the numerous rapids encountered by the survey party working in the territory lying adjacent to Hudson bay. As experienced canoemen are always engaged on these expeditions, accidents of a serious nature seldom occur.

FIG. 6. SUNDIAL AT CHIPEWYAN, ALTA.

Sundials are located at most of the important trading posts in the North, and at one time served a very useful purpose. This is thought to be one left by Sir John Franklin on one of his expeditions between 1820 and 1827, though this lacks confirmation.

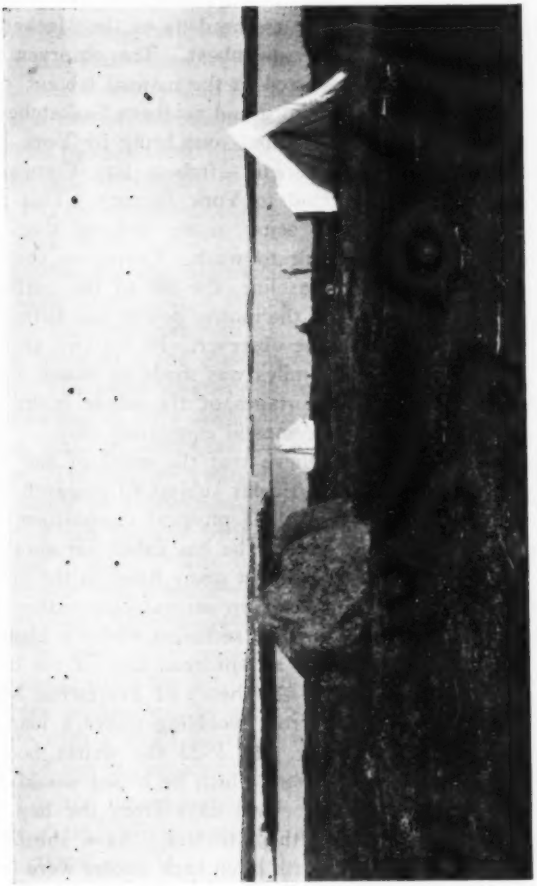


FIG. 7. NUELTIN LAKE NARROWS, N.W.T.

This is the most northerly point reached in 1922 by the party operating north from Cumberland House. It is slightly north of latitude 60°, and on the edge of what is known as the Barren Lands.

Transportation on Peace, Slave and Athabaska rivers was by canoe, and down the Mackenzie by means of a flat-bottomed skiff with an outboard motor. In the latter conveyance the trip of approximately 1000 miles was made to the delta of the Mackenzie, the return journey being made by steamboat. The observer was accompanied by one man who assisted in the manual labour.

Transportation in northern Manitoba and northern Saskatchewan was made by canoe, with two exceptions, one being by York boat down Reindeer lake and the other by Hudson Bay Company's schooner *Fort York* from Churchill to York Factory. This particular section of the country, being more isolated than the Mackenzie district, is more difficult to work. Owing to the impossibility of carrying sufficient gasoline, the aid of the outboard motor was out of the question, and the motive power was furnished by two canoemen in addition to the observer. In the two seasons a distance of approximately 3500 miles was made by canoe alone. In this distance there were 150 portages of the whole outfit and in addition many portages of instrumental equipment only.

The writer has been led to believe that the mind of the true scientist is occupied only by his particular subject of research, and that his love of work is so great that physical discomforts are ignored. The writer must confess that he has fallen far short of the recognized standard of a true scientist many times in the north. The ravenous insects of the air broke up several observations on Polaris and forced the observer to seek seclusion under a blanket. And once in the barren lands, after an enforced fast of ten days, the beauties and the complexities of the theory of Terrestrial Magnetism did not prevent his knees from wobbling under a load of 150 pounds on a two-mile portage. In 1923 the writer bought a pair of rubber boots at Port Nelson, which he hoped would last until Oxford House was reached. Two days from the bay the soles fell off the boots, rendering them useless. As a substitute for boots, old worn out mocassins with birch bark insoles were used for a time, following which socks only were used, and finally what was left of the socks. A distance of approximately 225 miles was made in this fashion, during the first 110 miles of which distance it was necessary to track the canoe up the river. During the month

required to complete this trip, snow was often on the ground and the writer again noticed that theories did not prove to be a soothing balm for bruised and frost bitten feet.

At each magnetic station observations have been taken for the three magnetic elements, namely, the declination, the dip, and the horizontal intensity, and in addition, observations on the sun and on Polaris for latitude, azimuth, and time.

The measurement of the declination involves two separate observations, namely, the determination of (a) the magnetic meridian and (b) the astronomical meridian, the angle between the two being the declination.

Declination and horizontal intensity observations are made with the same instrument, a magnetometer. The essential working part of the magnetometer consists of a hollow cylindrical magnet closed by a piece of plane glass at one end and by a lens at the other end. In some magnets there are two lines with their centres intersecting at right angles engraved on the inner side of the plane glass, while in others there is a set of cross hairs distinct from the glass. The magnet is suspended in a stirrup in a horizontal position by means of a phosphor bronze fibre. Small movements of the magnet can be read by means of a small reading telescope containing a scale. The instrument is mounted on the base of a theodolite with a horizontal cricle on which may be read the angle between the different pointings of the telescope.

The position of the suspended magnet determines the magnetic meridian, while the astronomical meridian is determined by observations on the sun or on Polaris. These latter observations are made with a small astronomical telescope mounted usually on the side of the magnetometer.

For the determination of the horizontal intensity of the magnetic field, two operations are required, called oscillations and deflections.

The operation termed oscillations is for the purpose of determining the time of one oscillation of the magnet, when it is suspended as for declination. The magnet swinging in this position acts as a horizontal pendulum. The time of oscillation depends on

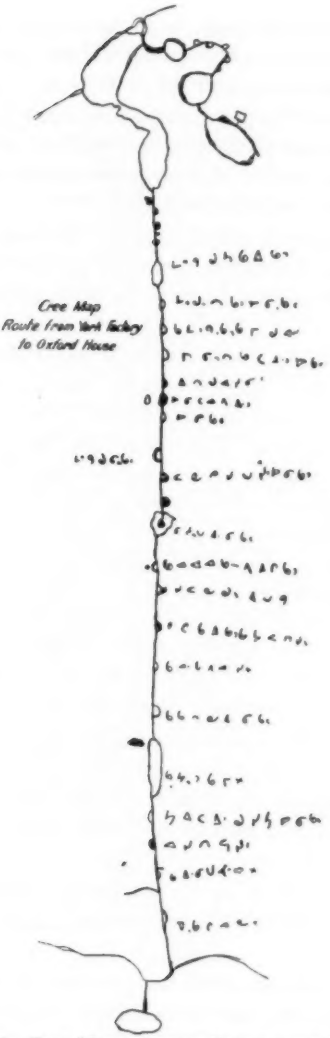


FIG. 8. CREE MAP SHOWING ROUTE FROM YORK FACTORY TO OXFORD HOUSE.

This map was used by the writer in 1923. It was drawn by an Indian at York Factory and gives information regarding the portages along the route.

the dimensions, mass, magnetic moment of the magnet, and the horizontal intensity of the earth's magnetic field.

For deflection observations the magnetometer is provided with a bar placed at right angles to the line of sight of the reading telescope. The magnet used during oscillations is placed on the bar as a deflector while a shorter magnet is suspended in the stirrup. The suspended magnet will be turned out of the magnetic meridian by an amount depending upon the relative strength of the deflecting magnet and the horizontal intensity. The operation serves to determine the ratio of the magnetic moment of the magnet to the horizontal intensity, while the oscillations give the product of the same two quantities. Thus from the time of one oscillation of the magnet and the angle through which the auxiliary magnet has been deflected, combined with a number of constant factors, both the horizontal intensity and the magnetic moment of the magnet may be computed.

The dip or inclination of the earth's magnetic field to the horizontal, is measured in the field by means of either a dip circle or an earth inductor.

In the case of the dip circle the direction of the earth's magnetic field is obtained by observing the position of the axis of a magnetized needle so supported as to be free to turn about a horizontal axis passing through its centre of gravity. The angle of dip is measured on a graduated circle concentric with the axle of the needle. In order to measure the angle of dip directly, the needle must swing in the plane of the magnetic meridian.

The principle on which the earth inductor depends is, that if a coil of insulated wire is rotated about a diameter there will be an alternating current induced in the coil unless the axis about which it rotates is parallel to the lines of force of the earth's field. Hence if the axis about which such a coil is rotated is adjusted till a sensitive galvanometer, connected to the coil through a commutator by which the alternating current is converted to a direct current, is undeflected, then the axis must be parallel to the lines of force of the earth's field and hence the inclination of the axis to the horizontal is the dip.

The magnetic instruments are compared before and after each

field season with the standard instruments for Canada which are situated at Agincourt, Ontario, and are under the supervision of the Meteorological Service of Canada. These comparisons give the corrections to be applied to reduce observations to the provisional International Magnetic Standard.

In addition to the magnetic instruments each survey party is equipped with half-seconds mean time chronometers and a wireless receiving set.

Since the diurnal variation of the magnetic elements at a particular place is a function of the local mean time, it is essential to know the local mean time of each magnetic observation. The chronometer correction on local mean time is deduced from the data obtained at the time of azimuth observations on the sun. The daily rate of the chronometer and its correction on standard time must be known—especially the former quantity, as it enters into the reduction of horizontal intensity observations. To secure these data time signals are received by wireless at least twice per day. The signals employed are usually those from Annapolis (N.S.S.). When Annapolis cannot be heard, as frequently happens in the Yukon Territory, the time signals from Panama (NBA), San Diego (NPL), and Honolulu (NPM) are utilized. As an example of the effectiveness of the portable wireless receiving outfit, signals were received at Aklavik, N.W.T., (ϕ 68°, λ 135°) the farthest north station thus far occupied, from the four above mentioned stations. The aerial consisted of about 130 feet of cotton covered No. 22 copper wire, both ends of which were raised about 25 feet above the ground. At the mouth of the Seal river on Hudson bay, (ϕ 59°, λ 95°) signals were received distinctly from Annapolis and Panama with a similar aerial at an average distance of only two feet from the ground.

Magnetic observations at each station are carried out during the day between 7^h and 18^h local mean time. Sometimes more than one day's observations are taken, and this is always the case when magnetic disturbances are either evident or suspected. During the observing period at a station at least 14 determinations of declination, 4 of dip, and 4 of horizontal intensity are obtained.

Although there has been a tremendous advance in the science

of Terrestrial Magnetism since the time of Gilbert, the whole subject is still problematical. The greatest unsolved problem of Terrestrial Magnetism relates to the cause of the main field. It has been demonstrated mathematically by Gauss and confirmed by Bauer, that 94% of the earth's magnetic field consists of an internal system, that 3% is due to an external system supposedly to be ascribed to electric currents circulating in the earth's atmosphere, and that 3% is due to a system probably such as that of vertical earth currents which pass from the atmosphere into the earth and *vice versa*. It is uncertain whether the cause of the internal system is magnetized matter, electric currents, or otherwise. If it is due to magnetized matter, then it must be explained how such matter can retain its magnetism under the high temperature that exists deep in the earth's interior, and if it is due to electric currents it must be explained how these are maintained.

The earth acts as a feeble magnet—the average intensity of magnetization for its entire volume being about 1/10000 that of very highly-magnetized steel. The magnetic poles of the earth are situated about 1200 miles from the geographical poles and they are not diametrically opposite each other. It is conceded that the magnetic north pole is in Boothia peninsula on the Arctic coast of Canada in about latitude 71° N and longitude 97° W, and that the magnetic south pole is in the Antarctic region in about latitude 73° S and longitude 155° E.

The magnetic poles are simply areas where the dipping needle stands perpendicular. The compass needle in these areas becomes useless since there is no horizontal force to hold it in position. The magnetic poles are subject to some sort of periodic motion which requires centuries for its completion. This motion of the poles is inferred from the secular variation of the magnetic elements, a variation proceeding from within the earth. The secular change —or the change with time—is not uniform over a period of years at any one place nor is it the same at different places. For example the average annual change in declination is about 10 minutes of arc at Churchill, about 4 minutes at Ottawa, and about zero at Dawson. The explanation of the phenomenon of secular variation is still being sought.

There are in many places in Canada local magnetic poles due to the presence in the earth of magnetic iron ore. The disturbance to the earth's magnetic field is usually confined to a comparatively small area. These centres of local attraction, when they occur along the coasts, and the shores of the Great Lakes, are of importance to navigation, and great care is taken to inform mariners as to their location and their effect.

Another interesting problem, not fully understood, is the diurnal variation of the magnetic elements, the main cause of which is situated outside the earth. The daily variation at a particular place is not constant throughout the year but is subject to seasonal changes. The sun's position above the horizon may be the controlling factor of this phenomenon since the magnetic needle has a maximum easterly pointing in the morning and a maximum westerly pointing in the afternoon. The average daily range in declination in Canada varies from about 17 to 30 minutes of arc, the range increasing with the latitude.

The orderly changes to which the magnetic elements are subject are frequently interrupted by very serious magnetic disturbances, or storms. During a disturbance the declination may vary by a degree or more in a short space of time. These disturbances usually arrive unexpectedly and often instantaneously over the face of the earth. They are due in some way to an influence exerted by the sun on the earth's upper atmosphere and are usually accompanied by auroral displays. In times of serious disturbances, the transcontinental telegraph lines are put out of commission for a period of time sometimes extending to days.

Broadly speaking, great magnetic storms are always accompanied by auroral displays, and *vice versa*, while they both occur only when there is a local disturbance (often manifested by sunspots) on the sun's surface; the converse in the latter case is not true, however—large sunspots are not necessarily accompanied by terrestrial phenomena. Again, the conditions at any time as regards magnetic disturbance tend to recur after a lapse of about 27.3 days, which is the period of the rotation of the sun relative to the earth. From this it is inferred that magnetic disturbance is due

to some solar influence originating in particular regions of the sun's surface and proceeding outwards in a limited stream. When this stream impinges itself on the earth, but not otherwise, magnetic disturbances and aurorae will result. If the region in the sun remains active and its emissions remain unchanged in relative direction, they will again strike the earth after a complete rotation of the sun and the magnetic disturbance will recur.

It has recently been shown that the phenomena of static, fading, and other peculiarities of radio transmission are influenced by the earth's magnetic field. Radio thus provides a means by which the strata of the upper atmosphere and their electrical properties can be explored.

The location and development of deposits of magnetic ore and other investigations of the geologist are aided by a knowledge of the facts about the earth's magnetism and the use of the instruments for measuring it. At the present time great interest is being taken in magnetic and electric methods of surveying mineral claims. Some of these methods depend entirely on the magnetic field of the earth and the natural currents of electricity beneath its surface. Several such methods are being tried out in the mineralized areas of Canada.

Canada occupies a strategic position on the face of the earth for the study of terrestrial magnetism. The magnetic north pole is on her Arctic coast and the curve of maximum auroral frequency extends across her northern territories from the mouth of the Mackenzie to Labrador. There occur in Northern Canada every known variety of magnetic and electric disturbance both internal and external. Although it is difficult to reach the immediate vicinity of the magnetic pole, high magnetic latitudes are readily accessible. The northern part of Canada, particularly that part adjacent to Hudson bay, offers a fertile field for both the theoretical and the practical investigation of terrestrial magnetism and its allied subjects. The importance of a knowledge of the behaviour of the magnetic elements—especially the declination for use in navigation—may be inferred from the fact that the declination

changes from about 45° west of north at the east entrance of Hudson strait to about 6° east of north at Churchill—a distance of approximately 1200 miles, and that the whole area is subject to more numerous and more severe disturbances than the lower latitudes.

The Dominion Observatory, under the direction of Mr. R. Meldrum Stewart, is conducting a vigorous research into the problems of terrestrial magnetism. This Sphinx-like science, born in antiquity, steeped in mystery, and whose motives are not easily guessed, has proposed a riddle which scientists have not been able to solve. Many scientific institutions, including the Dominion Observatory, have assumed the composite rôle of Oedipus with the hope of attaining his success but not his fate.

Dominion Observatory, Ottawa.
April, 1928.

DOMINION OBSERVATORY MAGNETIC STATIONS, 1907-27

Geographical Divisions	Station Occupations	Localities	Repeat Localities
Labrador	4	4	2
Newfoundland	2	2	1
Prince Edward Island	8	5	2
Nova Scotia	44	29	8
New Brunswick	23	20	5
Quebec	172	109	31
Ontario	285	176	49
Manitoba	108	75	17
Saskatchewan	70	45	16
Alberta	114	83	18
British Columbia	118	67	22
Yukon Territory	8	8	6
Northwest Territories	25	20	6
Totals	984	643	183

MAGNETIC OBSERVATIONS, 1921

Station	Latitude	Longitude	Date	Declination	Inclination	Horizontal Intensity
	° ′	° ′		West ° ′	°	γ
Louisburg	45 54.8	59 57.9	Sept. 1, 5	26 27.2	73 59.1	15608
Louisburg (Lighthouse Reserve)	45 54.2	59 57.9	" 3	26 24.8	74 03.2	15532
Sydney	46 08.8	60 11.6	Aug. 20-22	25 53.4	74 00.2	15602
Sydney (C.I. station)	46 08.8	60 11.6	" 22	25 59.2	.....	15586
Ingonish, South Bay	46 38.8	60 24.4	" 27-29	25 55.8	74 08.4	15605
Dingwall	46 55.0	60 28.5	" 24-26	26 51.4	74 30.2	15245
Grand Narrows	45 57.0	60 47.4	Sept. 6, 7	25 42.7	73 54.4	15742
Inverness	46 14.5	61 16.7	" 12	26 14.5	74 12.0	15724
Mulgrave, A	45 36.3	61 23.3	" 9, 10	24 50.7	73 37.1	16038
Mulgrave, C	45 36.3	61 23.3	" 8, 9	24 50.1	73 36.9	16040
Port Hood	46 01.0	61 31.7	" 14	25 09.7	74 03.8	15644
Grindstone, Magdalen Islands	47 22.4	61 51.1	" 20-23	26 29.4	75 04.2	14768
Amherst, Magdalen Islands	47 14.2	61 51.1	" 23, 24	26 51.4	75 02.3	14791
Souris	46 21.6	62 14.0	" 26, 27	24 35.0	74 25.4	15444
Pictou	45 40.9	62 44.0	" 16, 17	23 54.4	76 12.5	15682
Charlottetown	46 14.0	63 07.4	" 28-30	24 28.2	74 43.0	15213
Borden	46 15.0	63 40.5	Oct. 5, 6	24 04.7	74 58.9	14951
Summerside	46 24.4	63 46.8	" 1	23 47.2	74 58.3	14940
Tignish	46 56.4	64 02.2	" 3	24 41.6	75 30.8	14476
Cap des Rosiers	48 51.6	64 12.0	" 18-20	26 14.7	76 09.6	13920
Grand River	48 24.1	64 29.1	" 13	26 10.4	76 03.7	13978
Gaspe Basin	48 49.6	64 30.0	" 14, 15	26 02.8	76 10.7	13918
Magdalen River	49 15.3	65 19.8	" 22-25	27 00.8	76 33.4	13676
New Carlisle	48 00.5	65 20.5	" 11	25 11.5	75 58.0	14110
Mont Louis	49 14.0	65 44.0	" 26, 27	25 56.9	76 42.8	13559
New Richmond	48 10.3	65 52.0	" 9, 10	25 48.8	76 15.8	13888
Cape Chat	49 06.7	66 41.8	" 28, 29	25 24.1	76 51.4	13399
Matapedia	47 58.5	66 57.0	" 7, 8	23 50.2	76 18.4	13870
Matane	48 51.7	67 33.4	" 30, 31	25 08.2	76 46.8	13546
Megantic	45 35.7	70 52.7	Sept. 12	17 51.8	75 30.3	14799
Lyster	46 22.5	71 36.0	" 18-21	18 17.2	75 54.8	14505
Sherbrooke, B	45 25.5	71 56.8	" 29-Oct. 1	15 34.0	75 14.2	15425
Victoriaville	46 04.3	71 58.0	Sept. 26-28	16 57.8	76 03.8	14334
Stanstead	45 02.4	72 06.4	Oct. 3, 5	15 58.2	74 58.8	15311
Richmond	45 40.5	72 08.0	Sept. 6-9	19 03.5	74 56.8	15513
Sutton	45 06.5	72 35.3	Oct. 8, 9	16 42.5	74 48.5	15599
St. Johns	45 19.1	73 15.2	Sept. 2, 3	15 55.7	75 53.0	14611
Lacolle	45 06.1	73 20.4	Aug. 25, 26	15 31.6	75 47.5	14554
Huntingdon	45 05.6	74 10.3	" 29-31	13 35.8	75 53.8	14723
Ste. Agathe des Monts	46 04.8	74 17.8	Oct. 13, 14	12 47.7	76 40.2	13695
Morrisburg	44 54.4	75 09.6	Aug. 22-24	13 00.9	75 30.1	15213
Prescott	44 43.4	75 30.0	" 15-20	10 56.4	76 14.7	14338
Mont Laurier	46 33.8	75 30.4	Oct. 17-19	19 30.9	76 32.9	14222
Ottawa	45 23.6	75 43.0	June 13-16	13 49.6	75 38.3	14848
Ottawa	45 23.6	75 43.0	Aug. 5-8	13 50.5	75 38.4	14831
Tweed	44 30.1	77 18.6	Oct. 25-27	12 27.4	75 32.4	14878
Coe Hill	44 51.3	77 50.2	" 28-30	13 07.4	75 56.2	14650
Bancroft	45 04.7	77 52.4	Nov. 1-3	9 45.7	76 18.5	14366

MAGNETIC OBSERVATIONS, 1922

Station	Lat.	Long.	Date	Declination	Inclination	Horizontal Intensity
	° ′	° ′		West ° ′	° ′	γ
Ottawa	45 23.6	75 43.0	April 25-29	13 53.9	75 38.2	14824
			Oct. 17-19	13 57.2	75 40.4	14303
				East		
Kettle Rapids	56 24.0	94 33.0	May 31-June 4	7 02.0	82 59.6	07791
Mile 295, H.B.R.	56 07.4	95 24.0	June 5-6	10 25.6	82 46.4	07958
Mile 279 (Landing River), H.B.R.	56 01.7	95 45.0	June 8-9	10 44.9	82 43.4	07996
Mile 254, H.B.R.	55 55.1	96 18.0	May 27-28	12 10.8	82 09.5	08585
Mile 226 (Armstrong Lake), H.B.R.	55 41.6	96 54.6	June 11-12	13 15.4	82 10.5	08554
Mile 200, H.B.R.	55 26.8	97 22.0	May 24	14 01.3	81 52.4	08918
			June 13-14	14 01.2	81 49.7	08910

MAGNETIC OBSERVATIONS, 1932—*Continued*

Mile 150, H.B.R.	55 02.2	98 24.5	May 21-22	14 31.7	81 28.0	09202
			June 15	14 29.0	81 34.4	09206
Mile 100, H.B.R.	54 35.9	99 20.0	May 19-20	14 49.2	80 45.9	10058
			June 17	14 47.4	80 47.6	10027
Nueltin Lake Narrows	60 10.4	99 44.2	Aug. 17-18	18 03.6	84 18.3	06189
Nueltin Lake	59 51.6	100 05.2	Aug. 13-19	22 00.8	84 39.2	05811
Mile 42, H.B.R.	54 13.6	100 30.0	June 18-19	16 36.8	80 28.8	10330
Husky Portage	59 50.5	100 44.0	Aug. 29-30	13 53.0	83 49.6	06610
The Pas	53 49.9	101 14.0	Oct. 19-22	17 51.7	80 05.3	10785
Fort Hall Lake	59 28.2	101 17.7	Aug. 3	21 14.0	83 40.0	06780
Brochet Lake	58 32.9	101 21.2	Sept. 8	19 24.9	82 47.4	07915
Brochet Post	57 52.8	101 37.5	July 19	20 26.4	.....	.....
			Sept. 11-12	20 13.6	82 43.4	08016
Cochrane River	59 02.4	101 45.0	Sept. 4	25 57.4	83 40.2	06972
Beaver Lake	54 27.0	102 09.3	Oct. 3-4	18 50.1	80 25.4	10404
Cumberland House	53 57.7	102 18.0	Oct. 11-13	18 55.9	80 19.0	10560
Reindeer Lake	56 59.9	102 23.3	Sept. 16-17	21 46.4	81 56.5	08806
Sturgeon-weir River	54 55.1	102 34.0	June 28	19 56.7	80 34.6	10266
Pelican Narrows	55 07.9	102 53.8	July 2-3	20 31.1	80 43.1	10196
Reindeer River	55 55.7	102 55.7	July 9	19 28.1	.....	.....
			Sept. 26	19 33.0	81 27.8	09296
South Deer Lake	56 19.8	103 10.0	July 12	19 23.7	.....	09098
			Sept. 21-24	19 26.0	81 41.1	09088
Frog Portage	55 23.9	103 29.3	Sept. 28	21 01.2	80 48.6	10060
Rosetown	51 33.8	107 59.7	Oct. 10-11	22 20.3	77 00.9	13917
Kerrobert	51 55.4	109 08.4	Oct. 9	23 26.6	77 07.6	13770
Cheecham	56 17.3	110 50.1	Sept. 12-13	28 22.9	79 59.9	10793
Pickford	55 55.3	110 54.3	Sept. 10-11	27 37.6	79 56.2	11113
Chipewyan	58 42.7	111 08.8	Aug. 16-18	27 49.9	81 05.6	09567
Long Island	58 07.1	111 21.3	Aug. 31-Sept. 2	28 22.1	81 13.1	09519
T.S. Monument 4E	59 12.6	111 22.9	July 15	34 17.3	81 40.8	08896
McMurray	56 43.9	111 23.2	Sept. 4-6	28 58.5	79 58.6	10803
Poplar Point	57 53.9	111 25.4	Aug. 28	28 39.3	80 48.4	09921
T.S. Monument 18E	59 31.5	111 25.8	July 17-18	28 59.6	81 56.1	08728
Coronation	52 06.5	111 26.8	Oct. 5-6	23 56.7	76 34.9	14308
T.S. Monument A4	58 15.4	111 28.3	Aug. 29-30	28 46.7	81 19.4	09445
Fitzgerald	59 51.9	111 35.2	July 20-22	31 02.8	81 55.6	08657
Philomena	55 11.1	111 36.9	Sept. 19-21	27 45.0	78 45.7	12080
McKay	57 11.1	111 37.5	Aug. 24-25	30 03.5	79 48.6	11020
Chenal des Quatre Fourches	58 53.4	111 38.2	July 13	33 19.5	81 28.9	09298
Old Fort	57 24.6	111 38.4	Aug. 26-27	28 19.3	79 50.6	11137
Fort Smith	60 00.6	111 52.0	July 25	32 13.9	81 55.7	08654
Lac la Biche	54 46.9	111 57.2	Sept. 15-16	27 20.8	78 28.0	12348
Peace Point	59 07.3	112 25.4	July 10-11	32 22.0	81 37.9	08987
T.S. Monument T22	60 22.1	112 40.6	July 27-28	33 01.7	81 46.0	08892
Boyle	54 35.8	112 48.0	Sept. 23-25	27 39.4	78 09.4	12579
Jackfish River	59 04.4	112 53.8	July 6-9	34 27.5	80 53.4	09761
Pointe Ennuyeuse	60 47.0	113 02.8	July 29-31	33 20.9	82 21.4	08252
Thorhild	54 09.6	113 09.6	Sept. 28-29	27 14.8	77 49.8	12988
Old Fort	61 12.7	113 11.2	July 31-Aug. 1	39 47.7	82 13.1	08350
Twenty-ninth Base Line	58 46.6	113 19.9	July 5-6	32 27.0	80 40.7	10044
Bon Accord	53 49.8	113 24.9	Sept. 26-27	27 46.9	77 23.8	13411
Fort Resolution, A	61 10.1	113 40.5	Aug. 2-3	38 35.2	81 59.6	08573
Fort Resolution, B	61 10.2	113 40.5	Aug. 3-4	38 54.9	82 01.7	08594
Lacombe, A	52 27.6	113 45.0	Oct. 3	25 38.0	76 25.4	14327
Fifth Meridian	58 39.9	114 00.0	July 3-5	31 32.8	80 26.3	10214
Little Red River Post	58 24.6	114 44.9	July 1-2	32 31.9	80 13.7	10566
Vermilion Chutes	58 21.5	114 56.2	June 27-28	31 13.0	80 07.0	.....
Wabiskaw River	58 21.5	115 18.8	June 26-27	32 17.9	80 13.2	10431
Fort Vermilion	58 24.2	116 00.6	June 22-25	34 25.9	80 02.2	10727
Prairie Point	58 15.6	116 28.6	June 19-21	34 03.7	79 40.1	11012
Twenty-seventh Base Line	58 04.8	116 38.4	June 18-19	34 26.0	79 27.5	11224
Carcajou Point	57 47.2	117 01.8	June 14-15	32 21.1	79 16.0	11430
Twenty-fifth Base Line	57 23.4	117 07.7	June 12	30 17.2	79 04.0	11717
Whitemud River	56 40.1	117 10.2	June 7-8	30 47.5	78 27.7	12285
Brown's Landing	56 58.6	117 14.7	June 9-10	32 24.8	78 34.4	12142
Peace River	56 13.8	117 17.5	June 2-5	31 10.0	78 09.2	12618
Griffin Creek	56 00.0	117 46.8	May 31-June 1	31 05.6	77 37.9	13062
Dunvegan	55 55.5	118 35.2	May 29-30	30 18.4	78 06.9	12716
Range 6, Township 82	56 00.2	118 56.5	May 28-29	30 08.4	78 15.4	12528
Clear River	56 15.5	119 19.6	May 27	31 12.4	77 45.2	12975
Boundary	56 08.5	120 00.0	May 24-26	32 47.4	77 26.4	13302
Fort St. John	56 12.5	120 49.0	May 21-23	31 11.2	77 20.5	13260

MAGNETIC OBSERVATIONS, 1923

Station	Lat.	Long.	Date	Declination	Inclination	Hor. Int.
	° ′	° ′		West ° ′	° ′	γ
Ottawa	45 23.6	75 43.0	April 27-			
			May 3	14 00.0	75 38.6	14802
			Oct. 5-9	14 02.7	75 38.0	14789
				East		
York Factory	57 00.6	92 18.0	Aug. 20-27	3 04.5	83 20.1	07272
Port Nelson	57 03.1	92 35.9	Aug. 23-24	4 28.9	83 09.8	07460
Hayes River	56 36.7	92 38.8	Aug. 30	3 33.1	83 10.3	07473
Shamattawa River	56 22.5	92 51.0	Sept. 2-4	4 17.5	83 15.9	07394
Fox River	56 03.2	93 17.1	Sept. 7-8	6 42.8	82 36.0	08075
The Rock	55 39.8	93 30.8	Sept. 12-13	6 06.4	82 48.0	07830
Hayes River (First rapids north of Swampy Lake)	55 23.2	93 53.1	Sept. 18-19	5 26.2	82 20.5	08406
Swampy Lake	55 15.4	94 07.8	Sept. 20-21	8 56.8	82 06.5	08731
Churchill	58 45.7	94 13.2	Aug. 9-11	7 15.5	84 25.0	06088
Seal River	59 05.0	94 48.3	July 31-			
			Aug. 1	8 13.3	84 24.5	06104
Oxford House	54 57.8	95 15.6	Sept. 26-28	3 23.4	82 30.5	08311
Great Island	58 53.4	96 19.9	July 25-26	11 51.1	84 25.2	06097
Shethnanei Lake	58 50.2	97 35.3	July 22-23	14 25.8	84 00.2	06533
Thicket Portage	55 18.5	97 39.8	Oct. 11	18 51.3	82 04.0	08690
Norway House	53 59.1	97 49.8	Oct. 4-5	12 53.5	81 01.4	09792
Tadoule Lake	58 28.3	98 06.3	July 18	16 02.8	83 54.2	06673
Missi Falls	57 22.1	98 09.1	July 9-11	14 00.1	82 54.6	07635
Chipewyan Lake	57 56.8	98 30.3	July 14-15	15 41.6	83 18.1	07290
Southern Indian Lake	56 57.4	98 44.5	July 5	14 54.5	82 37.8	08013
Nepishkas Portage	56 29.9	99 57.6	July 2-3	16 09.6	81 59.5	08780
Churchill River	55 45.8	100 28.6	June 26-27	17 32.0	81 34.8	09176
Kississing River	55 27.4	100 55.5	June 13-14	18 11.4	81 23.7	09338
Pukatawagan	55 44.5	101 18.2	June 16-20	18 39.0	81 26.4	09316
Kississing Lake	55 09.7	101 25.4	June 10-11	18 34.1	81 07.4	09713
Baker's	54 40.7	101 39.6	June 6-7	20 11.9	80 38.8	10125
Sturgeon Landing	54 16.5	101 49.1	June 1-3	19 12.2	80 24.1	10452
Cumberland House	53 57.7	102 15.1	May 28-30	18 55.8	80 19.5	10553
McMurray	56 43.9	111 22.1	June 10-11	28 54.7	79 58.3	10810
Fort Smith	60 00.6	111 52.4	June 18-23	32 01.9	81 56.3	08616
Hay River	60 51.8	115 43.7	Sept. 6-8	35 58.2	81 22.8	09148
Hay River (Vale Point)	60 51.8	115 43.7	Sept. 12	36 01.3	81 22.6	09164
Brabant Harbour	61 04.2	116 34.6	June 28-29	38 03.0	81 20.7	09234
Providence	61 21.4	117 39.0	July 2-3	37 45.0	81 05.9	09466
Trout River	61 19.2	119 50.8	July 5	37 36.0	80 38.4	09871
Simpson, A	61 52.2	121 20.0	July 7-9	38 15.7	80 46.1	09751
Simpson, B	61 52.3	121 21.0	July 9-10	39 19.0	80 36.6	09795
North Nahanni River	62 17.5	123 21.4	July 12	38 59.0	80 25.5	10014
Wrigley, A	63 16.3	123 36.0	July 14-17	40 13.0	81 00.4	09433
Wrigley, B	63 16.3	123 36.0	July 16-17	40 16.1	81 00.0	09458
Birch Island	64 11.2	124 23.4	July 18	41 16.6	81 15.0	09128
Norman	64 54.3	125 34.6	July 20-21	41 29.0	81 26.7	08881
T.S. Monument 56N	65 31.4	127 39.3	July 23-24	40 43.1	81 09.2	09187
Good Hope, A	66 15.5	128 38.3	July 27-30	41 40.7	81 37.2	08687
Good Hope, B	66 15.2	128 38.3	July 28-31	41 38.8	81 38.0	08680
Sans Sault Rapids	65 44.8	128 47.6	July 25	41 28.9	81 09.7	09232
T.S. Monument O 44	66 43.8	129 51.1	Aug. 1	41 56.7	81 39.8	08595
T.S. Monument O 69	67 28.2	131 14.8	Aug. 4	41 40.4	81 51.2	08393
Arctic Red River	67 26.7	133 44.2	Aug. 6-7	44 57.3	81 44.3	08559
Middle Peel River	67 39.2	134 36.1	Aug. 11-12	45 00.6	81 25.8	08752
McPherson	67 26.4	134 52.6	Aug. 9-10	44 10.1	81 09.4	09120
Aklavik	68 13.5	134 59.7	Aug. 16-22	44 21.2	81 34.8	08584

[1] Magnetic storm. Observers, 1921-22-23, C. A. French and R. G. Madill.

THE ORBITS OF THE SPECTROSCOPIC COMPONENTS OF A PERSEI

By W. E. Harper

I have thought that a brief summary of an investigation concerning the binary nature of this star might be of interest to readers of the Journal. Its visual magnitude is 5.47 and spectral type F5 and its co-ordinates of position for 1900 are R.A.=3h 49m.2, Dec. = +50° 24′. It was announced as a spectroscopic binary showing double lines by the Lick Observatory in 1922 and since then 37 spectrograms have been obtained at this observatory.

Considerable difficulty was experienced in obtaining the period in which the components revolved the one about the other. Only a small percentage of the spectra showed double lines, which seemed to indicate that the orbit was quite eccentric with the orbital velocities large enough only around periastron for the lines to be resolved on our single prism dispersion. Eventually a period of 30.43 days was found to harmonize all the observations, and it was seen that on only three out of the thirty days would it be possible to obtain the component lines separate. As the determination of the orbital elements would depend greatly upon the portion of the curve where the component spectra were resolved an effort was made to secure as many observations as possible around that particular phase. Cloudy weather during the past eight months at the critical time has, however, militated against complete success in this regard.

Through the kindness of the Lick observers the velocities of their three plates were obtained, and as two of them showed the lines as double, it was decided to incorporate them with our own. Their three prism dispersion resolved the lines on the branch of the curve where our single prism of course would not, and, as these two observations happened to fall on that particular branch of the curve, it was all the more desirable to include them.

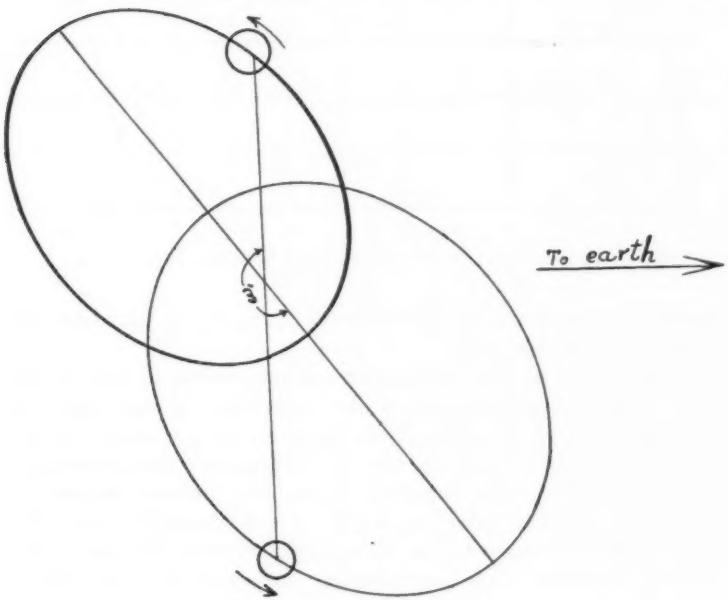
Without going into the details of the work it may be said that preliminary values of the elements were obtained in the ordinary

graphical way and then improved values were obtained by the method of least squares. Thirty-two observation equations, with seven unknowns, when solved yielded the following values of the elements, to which the corresponding probable errors are attached.

FINAL ELEMENTS

$P = 30.4338 \pm .0009$ days
$e = .612 \pm .013$
$\omega_2 = 214°.36 \pm 6°.63$
$\omega_1 = 34°.36 \pm 6°.63$
$\gamma = +25.66 \pm 0.49$ km.
$K_1 = 49.38 \pm 2.11$ km.
$K_2 = 57.10 \pm 2.21$ km.
$T =$ J.D. 2423797.270 $\pm$ .181 days

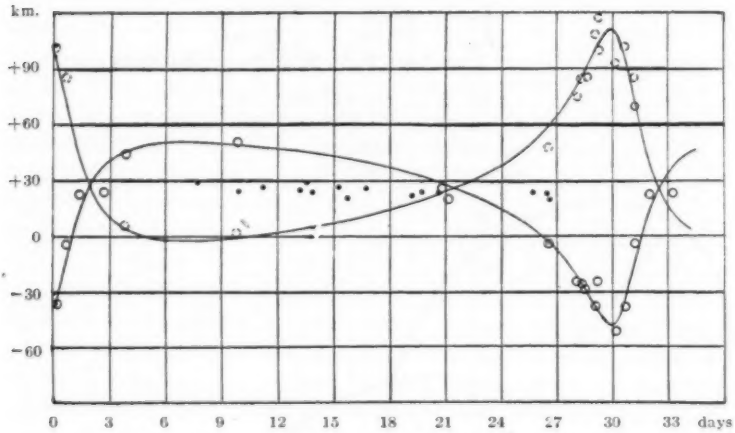
$a_1 \sin i = 16\,343\,000$ km.
$a_2 \sin i = 18\,898\,000$ km.
$m_1 \sin^3 i = 1.012 \odot$
$m_2 \sin^3 i = 0.875 \odot$



Projected orbit of A Persei

There seems to be a tendency for the observed velocities to become increasingly more positive year by year as if this system were revolving about another in a much greater period of time. Future observations are necessary to determine whether this peculiar trend of the residuals has a real physical significance or not.

As mentioned above and as may be noted from the radial velocity curves and from the graph of the orbits, the eccentricity is exceptionally high. There is only one other F-type with higher eccentricity if we except the visual binaries. In fact with such



Velocity Curves of A Persei, showing individual observations

exception there are only nine between types A_5 to G_5 where the eccentricity exceeds 0.49.

The masses of each component are comparable to that of the sun. There is always present the uncertainty in the angle of inclination (i) of the orbit. Here, however, we can make a pretty fair guess at it by making use of Eddington's mass-luminosity relation. The absolute magnitude of the star has been determined by Young and the author as +3.25. On Eddington's curve this corresponds to a mass for an F_5 star of 1.49 times the sun. Our derived elements show an average mass for the components,

multiplied by $\sin^3 i$, to be 0.944 times the sun. Hence 1.49 $\sin^3 i$=0.944 whence i=59°.2.

The theory of probability calls for the average value of a great number of orbits to be 57°.3, but practical considerations suggest that the average will be slightly greater than this. Reversing the process it may be looked upon as one more observed point on Eddington's curve for assuming $\sin^3 i$=0.65 as is usually done the resulting mass of one component is 1.45 times the sun in good agreement with the curve value of 1.49.

On the radial velocity curve shown individual observations are plotted, the broken circles referring to component II. The small filled circles represent observations unused in the solution.

Dominion Astrophysical Observatory,
April, 1928.

THE NATURE OF MOLECULES

By Carlyle S. Beals

The precise nature of atoms is a subject which has been studied very intensively by scientists all over the world of recent years. The results of these researches have yielded very definite information as to the structure of the atom. Formerly believed to be a single indivisible particle, the atom has been shown to be a very complex structure indeed. The atom has been compared to a miniature solar system consisting as it does of a massive central nucleus with a number of lighter bodies called electrons revolving around it. The number of electrons revolving around the nucleus varies from one in the case of hydrogen to ninety-two for uranium, the heaviest atom of all.

It has long been known that two or more different atoms may combine to form a molecule. Molecules may be formed by the union of atoms of the same element or the atoms of a number of different elements may together make up a molecule. Among organic compounds many very complex molecules are known, some containing as many as fifty atoms. The exact nature of molecules has long remained a mystery, and it has only been of comparatively recent years with the more or less complete development of atomic theory that substantial progress has been made in the study of molecular structure.

While a number of different methods may be used in the study of atoms and molecules the spectroscope has proved to be the most powerful instrument yet devised for determining their more detailed structure. It is of interest to note that the methods of optical spectroscopy, upon which the astronomer relies for the greater part of his information concerning the stars, is also the principal means of determining the nature of atoms and molecules. There is, in fact, a very close connection between the study of astronomy and the study of atomic and molecular structure. A knowledge of atomic structure and of molecular structure as well is essential for a clear understanding of the physical conditions of the stars. The method of the astronomer is to determine, by means of the

spectroscope, the state of the atoms or molecules in a given star, and from the data gained in this way, to make deductions concerning the temperature, pressure, and other physical conditions existing in the atmosphere of the star. The researches of the astronomer, in a similar way, have been of great assistance to the physicist in his study of atoms and molecules. Matter in the stars may exist under conditions which cannot be duplicated on the earth, and the study of the stars has provided new information about the constitution of matter which might never otherwise have come to light.

The work of the Dominion Astrophysical Observatory at Victoria has until recently consisted entirely of the study of stellar spectra. During the past year, however, a certain amount of time has been devoted to the study of laboratory spectra. The work for the most part has consisted of a study of the spectra of molecules in the hope of adding something to the existing knowledge concerning molecular structure. The character of the work may perhaps be best illustrated by a brief survey of our present knowledge of molecules.

The simplest molecule, that composed of only two atoms, is believed to be a structure somewhat resembling a dumbbell, the nuclei of the two atoms in the molecule being represented by the two spherical knobs on the ends of the dumbbell. There is no material connection between the two atomic nuclei, but they are held in their relative positions by the action of electrostatic forces. In the case of complex atoms the majority of the electrons belonging to each atom revolve about their nucleus as though the atoms had no connection with one another. Some of the electrons, however, revolve about the molecular configuration, as a whole, and their motion has an important bearing on the mechanical stability of the molecule.

With this picture of the general form of the molecule in our minds we are in a position to discuss its internal motions. These motions are of three kinds. First, the orbital motion of the external electrons, which move around the molecular configuration in circular or elliptical paths. The second type of motion consists of a vibration of the two atomic nuclei along a line joining their centres. These vibrations are similar in character to those which would be

executed by a weight suspended by a coil spring or an elastic band. The third type of motion is a rotation of the molecule, as a whole, about an axis perpendicular to the line joining the two nuclei. This type of motion is analogous to that of a steam engine governor, the motion of the two atomic nuclei being precisely similar to that of the two bobs on the governor.

When the molecules of a gas are subjected to certain external influences, such as high temperature or excitation by electrical discharges, changes take place in the motions of the individual molecules. These changes may affect the orbital motion of the electrons, the vibration of the nuclei or the rotational motion of the molecule. When such changes take place the molecule emits light rays of definite frequencies, and it is the analysis of these light rays by means of the spectroscope which provides a means of studying the structure of the molecule. The study of molecular spectra is being carried on by research workers in many parts of the world and has become one of the most important branches of modern scientific research.

Dominion Astrophysical Observatory,
Victoria, B.C.

THE D.A.O. ASTROPHYSICAL CLUB

Seminar No. 58, Feb. 10, 1928.

EMISSION STARS OF EARLY TYPE WITH PARTICULAR REFERENCE TO *PHI* PERSEI

About one star in every thousand of the earlier types shows emission lines. While all types from the late O's to *A*2 are represented, the phenomenon is most marked from *B*0 to *B*5. Taking the Balmer series of hydrogen as typical of such radiation, it has long been known that the intensity of such emission increases progressively to the redward end. As a corollary to that fact we may state that the greater the intensity of the first member, $H\alpha$, the greater will be the number of the Balmer lines showing emission.

While all stars of *B*-type are concentrated towards the galactic plane it is especially marked in the case of those showing emission. From cluster parallaxes and proper motion data we learn that these are stars of enormous luminosities, being considerably brighter than those of the same type showing no emission. And yet early type and high luminosity are not sufficient to ensure emission, as some stars like Pleione, the lost Pleiad, lose their emission without change of brightness or variation of type.

One of the best observed stars of this class is ϕ Persei, upon which a host of observers have worked since its discovery as an emission star by Pickering in 1889. Campbell discovered its variable radial velocity in 1900 and Cannon at Ottawa determined its orbit in 1910. Simple elliptic motion would not satisfy the irregular velocity curve obtained, and a third body was assumed to be present in the system. Tidal effects due to this third body were held responsible for the changes in the spectrum so clearly shown in Cannon's photographs.

Jordan at Allegheny, from a series of spectra taken about the same time, corroborated Cannon's findings and among other things showed that the emission bands also shared in the oscillatory motion in the determined period of 126.5 days but with only about half the amplitude.

Ludendorff found certain of the faint lines double and deduced orbits for each component. If real, this doubling would not be revealed on the smaller dispersion employed at Ottawa and Allegheny.

Recently Lockyer at Sidmouth (see M.N. 86, page 474), using a prismatic camera with double the dispersion of Ottawa or Allegheny, secured a run of plates on 82 nights within one cycle and thus was able to follow more closely the changes taking place in the spectrum from time to time. Briefly expressed, the hydrogen lines consist of broad absorption bands 20 angstroms in width, overlaid with emission bands 7 angstroms wide, the latter being divided into two components by narrow central absorption. These narrow lines of absorption have been the basis of the velocity determinations. Lockyer noted that the relative intensities of the emission components, into which the bands were divided, varied in intensity throughout the period. Eye estimates, followed by wedge measures later, showed that these variations were cyclical in character and could be made to reveal the period equally well with the observed changes in the radial velocity. This was his main contribution.

He also describes the other lines found in the spectrum to which attention had been called by previous investigators on numerous occasions. Most interesting is the existence of the series of enhanced lines such as are found in α Cygni, a giant star of type *A*2. These ionized lines, mostly of iron, would not naturally be looked for in an early *B*-star, but the existence of such there is confirmation of the belief that these emission *B*-stars are giants at temperatures lower than ordinarily associated with a *B*-star.

W. E. HARPER.

Seminar No. 59, February 17, 1928.

INVESTIGATIONS OF CEPHEID VARIABLES—SHAPLEY, H.C. 313, 314, 315 AND 316

I. The Period-Spectrum relation.

In H.C. 313 Dr. Shapley and Miss Margaret L. Walton investigate the period-spectrum relation for 70 galactic Cepheids. The period-luminosity relation found for Cepheids in globular clusters and in the Magellanic clouds has not been derived from the galactic cepheids due chiefly to insufficient data on their parallaxes.

The spectra were classified from the plates in the Harvard Collection by Miss Cannon. When the median spectrum is plotted against the period the 70 stars fall on a smooth curve. The types range from *A*2.0 to *G*7.5, the corresponding periods being 0.4 to

40 days. So well does the curve represent the 70 stars that the average deviation is only 2.1 spectral units.

No progressive dependence of range of spectrum on length of period or on median spectral class is found. The average range is slightly more than one spectral division.

The relation is so definite that the period-spectrum curve may be used to estimate a period of a Cepheid when once the spectrum is known. The period of R. Muscae was thus corrected from 0.88 days to 7.5100 days by Hertzsprung.

II. The Period-Luminosity Relation for Galactic Cepheids.

In H.C. 314 Shapley uses the period-spectrum curve to derive the period-luminosity relation for these stars. From the fundamental gravitational relation of the pulsation theory, *i.e.*, that $P\sqrt{\rho}$=a constant, it is easily shown that the Bolometric absolute magnitude, temperature, period and mass are connected by the equation

$$M_0 - M = 10 \log T - 10 \log T_0 + \frac{10}{3} \log P - \frac{10}{3} \log P_0 + \frac{5}{3} \log \mu - \frac{5}{3} \log \mu_0.$$

As a first approximation the masses are considered constant and the initial conditions of P_0, T_0, M_0 fixed for a star of Class C_0, to here $M_0 = -1.9$, $T_0 = 5{,}500$ and $\log P_0$ from the period spectrum curve is 0.59. The equation then becomes

$$M_0 - M = (10 \log T - 37.40) + \left(\frac{10}{3} \log P - 1.97\right)$$

which is used to compute bolometric absolute magnitudes for all types from A_0 to $G7.5$. The resulting luminosities indicate that the mass factor is not negligible, so that two approximations are made to obtain the final values of M_B. These are converted into the visual absolute magnitudes M_v, and a comparison is made with the period-luminosity curves for the Cepheids in the Magellanic clouds and globular clusters. The agreement is very good, but Shapley suggests that a still better agreement would result if Eddington's theory of cepheid pulsation be used in which the fundamental gravitational relation is

$$P^2\rho(3\gamma - 4) = \text{constant}.$$

The conclusion that the period-luminosity curve for galactic cepheids is in close agreement with the curve derived from the

variables in the star clouds and clusters is reached quite independent of data on proper motion, radial velocity or parallax, and is without assumption as to the theory of cepheid variation.

III. Cluster Variables.

In H.C. 315 Shapley discusses the mean periods and median apparent magnitudes of 243 cluster type cepheids, in Messier 3, 5, 15 and ω Centaurus. It is found that when the variables are divided into mean period groups the groups show no dispersion in median apparent magnitude, indicating that there is no range in total luminosity for these stars.

The constant median apparent magnitude is a fundamental property of the cluster variables and is difficult to explain on the pulsation theory. The extreme periods have a ratio of 3 to 1, which demands a range in density of 9 to 1, and it is clear that either the masses or surface areas must change considerably throughout the range of periods. Shapley adopts the essential identity of mass for these variables and shows from the evidence of the mean spectra of 25 galactic cluster type variables and the colour indices of short and long period groups in Messier 15 (39 stars) and in Messier 5 (17 stars) that differences in colour and surface cannot be maintained.

There seems no alternative but to conclude that the simple period density relation of the pulsating theory fails for these variables. It may be, as Shapley suggests, that the pulsation period should be associated with the density of the nucleus in the interior, rather than the mean density, different periods indicating different stages in the evolution of the nucleus which leaves the total mass, mean density, size and surface brightness constant.

IV. Beta Doradus—a New Fourth Magnitude Cepheid.

In H.C. 316, Dr. Shapley and Miss M. Walton discuss 210 photographic observations of this star which was found to be a cepheid from the spectroscopic investigations of Palmer, R. E. Wilson, Lunt and Miss Applegate. The mean photographic light curve varies from 4.25 to 5.65 in a period of 9.8417 days. The spectrum varies from *F*8 at minimum to *F*2 near maximum. The proper motion of $0''.016 \pm 0.008$ given by Boss is in agreement with other long period cepheids. The parallax is $0''.0043$ deduced from the photographic period-luminosity curve given in H.B. 845, 6, 1927.

J. A. Pearce

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Observation of Meteors and Fireballs

We are somewhat lacking in Canada in the observation of meteors and fireballs. This is largely due, no doubt, to our sparse population, but if some enthusiastic observer—amateur or professional—would organize the work and keep in touch with the observers substantial results would follow.

In a contribution to the New Zealand Astronomical Society, Mr. R. A. McIntosh, of Auckland, gives interesting information regarding Fireballs, and also suggestions to observers. In the hope that it may lead someone to undertake this branch of astronomical work, I print a portion of it herewith.

The observer of meteors, in the course of his work, is sometimes rewarded by the spectacle of a brilliant fireball, which, bursting suddenly into prominence high in the sky, passes slowly across the heavens with a brilliancy often surpassing that of the moon. A wonderful variety is shown in different fireballs. Though more often silent, they are sometimes accompanied by a loud detonation—generally a sign of their aerolitic nature. They may flash across a long arc of the sky with a speed rivalling a flash of lightning, or they may travel so slowly that the most inexperienced eye has time to gather an excellent impression of the details of their flight. Sometimes the multi-coloured nucleus breaks up and vanishes as suddenly as it had forced itself upon our notice; again it may fade out slowly until reduced to a faint spark before melting into obscurity. Fluctuations in light are often noticeable, and a curious halting, hesitant motion may be observed in some of the large, slow-moving types. The slow-movers evolve trains of sparks; the swifter project streaks of phosphoresence upon the sky, and this trail—the consumed material thrown off from the incandescent nucleus—may linger for many minutes, assuming irregular shapes as it slowly drifts in the air currents of the higher atmosphere.

The Southern Cross

It may with truth be claimed that the traveller who first saw and described the famous constellation, the Southern Cross, was an American. When Americo Vespucci, on his first voyage saw the constellation, he wrote in triumph that he had beheld the Cross—

and Dante's "four stars." A friend has drawn my attention to the poet's description:—

> To the right I turned and fixed my mind
> On the other pole attentive, where I saw
> Four stars ne'er seen before save by the ken
> Of our first parents.
> Heaven of their ray seemed joyous.
> O, thou northern site, bereft
> Indeed, and widowed, since of these deprived

This quotation is from Canto I or the "Purgatorio," in Cary's translation.

The Cross lies directly south of the constellation Crater, and about 30° of the Pole. The precession of the equinoxes is carrying the Cross steadily southward, and it is said to be a fact that the constellation was last seen on the horizon in the latitude of Judea about the time of Christ's crucifixion. I remember that at the season of the year we were at Assouan the four stars (perhaps only two of them, really) were barely visible on the horizon for a short time in the early evening. I do not agree with Pigafetta that it is such a "Croce maravigliosa," but then I was more gradually introduced to it than he, and I didn't see it with his deeply religious and fervent eyes.

It must not be forgotten that Job saw the Cross as a familiar heavenly series in his northern skies, as did many another ancient and reliable astronomer, and yet they were not much impressed by this kite-like group. Let me add that of the four stars that outline the Cross the third largest (Gamma, at the top of the Cross) is orange-coloured; the others are white.—(By Casey A. Wood in "Sketches from the Notebook of a Naturalist Traveller in Oceania during the Year 1923"—Smithsonian Annual Report, 1924).

Some English Precursors of Newton

By E. G. Hogg*

Nicolas Copernicus died on May 23rd, 1543. In his great astronomical treatise he showed that the main facts of the Solar system could be much more easily explained by the rotation of the earth on its axis, combined with a motion of revolution about the

sun, than by the complicated Ptolemaic doctrine, which had been the accepted planetary theory for more than a thousand years. Within a few years of the promulgation of this theory, so novel, startling, and repugnant to ordinary experience, three Englishmen were found bold enough to advocate it—Robert Recorde, John Field, and John Dee. Of the life of the first-named we know little: he was an eminent physician and an able mathematician. In his medical capacity he is believed to have been attached to the household of Edward VI. and Mary, and he undoubtedly died in a debtor's prison in the first year of Elizabeth's reign. He has the merit of having introduced algebra into England in a book named "The Whetstone of Witte," which readers of Scott may remember constituted the sole literary possession of old Prapbois the miser. Recorde also wrote a dialogue enlightened by many touches of satire, called "The Castle of Knowledge," which contains the first known printed reference in the English language to the doctrine of Copernicus.

John Field has earned for himself the title of the "Proto-Copernican of England," as he was the first English astronomer who adopted the heliocentric theory of the solar system. In his "Ephemeris" for 1557 he gave a systematic exposition of the new hypothesis. Dr. John Dee appears in this connexion, as it was he who instigated, and patronized with a preface, Field's book. In 1547 Dee appears to have visited the Low Countries for scientific purposes, and he subsequently studied and lectured at the Universities of Paris and Louvain, and we may safely conclude that it was then that he became a disciple of Copernicus. He was a good mathematician, but any reputation he may have acquired in that direction has been eclipsed by his fame as a magician. He was the favourite soothsayer of Queen Elizabeth and Leicester, and, with the assistance of a certain Edward Kelly, he succeeded in imposing his pretensions on several of the greatest personages in Europe. He and his confederate, through their supposed mastery of the great alchemistic secret, procured for themselves such affluence that, according to the popular belief, Dee's son was accustomed to play at quoits with gold produced by means of the "philosophical powder of projection." Finally the pair quarrelled. Dee was recalled to England by Elizabeth, and receiving, after the manner of that Prin-

cess, more promises than pay, died in poverty in the fifth year of her successor's reign. The magic crystal which he professed to have received from the hand of an angel may still be seen in the British Museum.

In either 1617 or 1619—for there is a doubt on the subject—was born at Toxteth, near Liverpool, one Jeremiah Horrocks, whom Sir John Herschel has justly styled "the pride and boast of British astronomy." The child of a Lancashire family of little pretensions and less means, he was admitted to Emmanuel College, Cambridge, as a sizar, on May 18th, 1632. A passion for astronomy early seized him, but his tastes met with neither encouragement nor cultivation at Cambridge, which at that time afforded no form of scientific training. Books were his sole instructors, and his slender resources the limits of his choice. After years at the University he was summoned home, and he passed his remaining years at Hoole, a desolate hamlet about five miles south of Preston. Though he is sometimes styled the Rev. Jeremiah Horrocks, there is no evidence that he ever took holy orders; in all probability he acted as lay-reader at the Church at Hoole. His life was spent in poverty, for, as an American professor of astronomy rather quaintly puts it, he "united in his own person two of the mostly poorly paid professions, an unbeneficent (sic) clergyman of the Established Church and an astronomer."

Horrocks managed to find time for astronomical observations, and his zeal was further quickened by meeting, in 1636, a congenial spirit in William Crabtree, a clothier, of Broughton, near Manchester, through whom he became acquainted with the famous Rudolphine Tables in which Kepler had recorded the calculated places of the then known planetary bodies. In studying these he became convinced that a transit of Venus, which Kepler had failed to predict, would actually occur on November 24th, 1639. At Hoole, first among astronomers of all ages, he observed the passage of Venus across the sun's disc. November 24th fell on a Sunday, and as the critical hour approached Horrocks was summoned to his clerical duties: he returned, however, just in time to witness, as the clouds parted at a quarter past three, the punctual verification of his forecast in the projection of the dark body of the planet on the sun's

surface. An interval of half an hour before sunset gave him time to make a series of observations surprisingly accurate, considering that a telescope bought for half a crown and a circle of six inches diameter, traced with a pair of compasses on a sheet of paper, was the primitive apparatus he employed.

Horrocks did not long survive this solitary triumph of his life. After many postponements, he at last saw a prospect of one day's extrication from his irksome duties and fixed January 4th, 1641, for a visit of science and sympathy with his friend, Crabtree. On the morning of the 3rd, however, he suddenly died. On him might safely be passed the usually somewhat problematical eulogium, "He had done great things, had he lived." Short as was his life and few his opportunities, he left the impress of his genius on astronomical science. The movements of the moon had not yet been brought within the dominion of the three Laws of Kepler to which the planetary motions were subject. Horrocks first pointed out that the irregularities in the movements of our satellite could be harmonized into an orderly scheme by supposing her to revolve in an ellipse of which the earth occupied one focus—the eccentricity of such ellipse being variable and its major axis directly rotatory. Both these conditions Newton—forty years later—demonstrated to follow necessarily from the law of gravitation! We are lost in admiration at the acuteness and sagacity of the intellect which could advance and justify this proposition when we consider the circumstances under which it was made.

*In "Astronomical Notes", published by the New Zealand Astronomical Society.

REVIEW OF PUBLICATIONS

THE CHARACTERISTICS OF SPECTROSCOPIC BINARY STARS

By Arthur Beer, Berlin-Babelsberg, Vol. V, Pt. 6*

Reviewed by J. S. Plaskett

This quarto book of 131 pages contains a complete discussion of the relations between the various elements of spectroscopic binary systems. All the stars with variable radial velocity, 1002 in number, and all of the latter having determined orbits, 282 in number, all known to March 1, 1927, are thoroughly discussed in this publication. After the appearance of Campbell's Second Catalogue of Spectroscopic Binaries in 1910, the observatory of Berlin-Babelsberg kept a card catalogue of all binaries and orbits published which after 1922 was turned over to Dr. Beer to maintain and discuss. The appearance of the Third Catalogue in 1924, after this discussion was commenced, led to a comparison of the two sources and very general agreement was found, the difference being noted on p. 122. There have since been added 150 binaries with 30 orbits (p. 7) although some of these were not included in the discussion.

Dr. Beer realizes that the variable radial velocities found are not in every case due to the simple revolution of the one star about the other, but are in some cases due possibly to the pulsation or other disturbance of a single star, in others to a combination of pulsation and revolution, to the presence of a third body or other causes. The second section of the monograph, the first being given to the collection and discussion of the observational data, is devoted to an attempt to find a criterion which will enable simple orbital motion to be differentiated from the other possible causes of variable radial velocity. The criterion he discusses is called the

*Presented at Seminar No. 57, Dominion Astrophysical Observatory, February 3, 1928.

period-amplitude relation, the product of half the amplitude or range in velocity into the cube root of the period. He shows that this depends upon the eccentricity, the inclination of the plane of the orbit, the total mass of the system and the ratio of the masses of the two component stars. The change in eccentricity and inclination is small, but there is a great range in the masses and in their ratios, and if it can be shown that these vary so as to maintain the period amplitude value constant, this will form a criterion of pure orbital motion.

From the 282 stars with known orbits he selects 70 systems in which both spectra show, or which are eclipsing variables, as our knowledge about these systems is more complete and reliable. Dividing these 70 stars into six groups of different lengths of period he computes the value of the period-amplitude relation for each group and finds the agreement good, the mean value being 125.1 ± 6.0. He then plots the known positions of 434 objects, the 282 orbits with the addition of the second component for many of them with the amplitudes and the logarithm of ten times the period as co-ordinates and finds that although there is a general agreement with the curve of period amplitude equal to 125.1, called the normal PK curve, there is a very large scatter above and below this curve, especially for periods less than 22 days. The positions above the curve are due to abnormally great mass, and below, partly to small mass and partly to variable velocities not due to simple orbital motion.

Analyzing further, he finds the binary orbits showing only one spectrum are generally below the PK curve and its mean value for these stars is 84.7. This may be ascribed to either smaller masses or smaller ratio of the masses. Analyzing still farther, those single spectrum stars below the normal PK curve and dividing them into early type or hotter stars and into giants and dwarfs, he finds that the giants fit the normal PK curve fairly well, there is a great scatter of the early types, mostly below this curve, while the dwarfs group around a PK value of 62.4, just half the normal. Analysis shows that this must be due partly to smaller mass but mostly to a much smaller ratio of the masses of primary and secondary stars. Below the scatter region of these curves, occur

a number of stars, mostly variable stars known as Cepheids and pseudo-Cepheids, whose variable radial velocity is certainly not wholly due to orbital motion. The period amplitude relation may be used, then, though not with great certainty, to differentiate pure orbital motion from the other causes of variable radial velocity.

The other two sections of the monograph dealing with the frequency of period and type, with the relations between period and eccentricity, with the total luminosities and masses and other relations will be reviewed at a later meeting of the seminar.

THE AURORA BOREALIS*

By C. S. Beals

A distinction is made between the Polar aurora, a term descriptive of the brilliant displays observed in high latitudes, and the non-Polar aurora which may be observed in any latitude and which takes the form of a faint, diffuse light in the night sky. The spectra of Polar and of the non-Polar aurora have been observed by Vegard[1], Rayleigh[2], Babcock[3] and others.

The main features of the spectrum appear to be common to both types of aurora and consist of the negative bands of nitrogen and the green line λ 5577 which up till recently had not been observed in the laboratory.

Vegard suggested that the upper regions of the atmosphere contained large quantities of solid nitrogen particles held in suspension by electric force, and that the green line of the auroral spectrum was due to the bombardment of these particles by electric rays from the sun. Vegard observed a line or band approximately in the position of the line λ 5577 when he bombarded solid nitrogen with cathode rays in the laboratory and he considered that his results confirmed his theory of the constitution of the upper atmosphere.

Vegard's conclusions were criticized on theoretical grounds by Atkinson[4] and his experimental results were called in question by McLennan and Shrum[5], who repeated his work with solid nitrogen

*Presented at Seminar No. 56, Dominion Astrophysical Observatory, January 27, 1928.

and found that the "line" at λ 5577 observed by him could be resolved into three bands.

Later McLennan and Shrum[6] were able to produce the aurora line λ 5577 in the laboratory by passing an electric discharge through mixtures of oxygen and helium. They also observed the line, though more faintly, in pure oxygen. The wave length of the line was accurately measured by McLennan and McLeod[7] using a Fabry and Perot interferometer and was shown to agree closely with the interferometer measures of Babcock of the auroral line in the spectrum of the night sky. McLennan and Shrum have suggested the possibility that metastable helium may act as the exciting agent in the production of the auroral spectrum. This suggestion would tend to confirm the existence of the so-called helium layer in the upper regions of the atmosphere.

Vegard and Störmer fixed the minimum height of auroral displays at about 80 kilometers above the earth, but a recent observation of an aurora in Alaska[8] and the faint sounds which have been observed to accompany auroral displays in Northern Canada[9] indicate that the aurora may reach much lower altitudes and may even be observed within a few hundred feet of the earth. In connection with theories of the aurora, it is obviously of importance to confirm the existence of these low altitude displays and to investigate the character of their spectra.

[1]Vegard, *Phil. Mag.* 6 Vol. 46, p. 193 (1923).
[2]Rayleigh, *Proc. Roy. Soc.* A. Vol. 100, p. 367 (1921).
[3]Babcock, *Ap. J.* Vol. 57, p. 209 (1923).
[4]Atkinson, *Proc. Roy. Soc.* A. Vol. 106, p. 429 (1924).
[5]McLennan and Shrum, *Proc. Roy. Soc.* A. 106, p. 138 (1924).
[6]McLennan and Shrum, *Proc. Roy. Soc.* A. Vol. 108, p. 501 (1925).
[7]McLennan and McLeod, *Proc. Roy. Soc.* A. Vol. 115, p. 515 (1927).
[8]Johnson, *Pub. A.S.P.* Dec., 1927.
[9]*Jour. R.A.S.C.*, Vol. XXII, p. 28, Jan. 1928.

MEETINGS OF THE SOCIETY

AT MONTREAL

The Vice-President, Mr. H. E. S. Asbury, in the chair. New members were elected as follows:

Mr. G. Harper Hall,
Mr. J. A. Morris.

The lecturer was Professor A. S. Eve, D.Sc., F.R.S., his subject being Motion and the Heavenly Bodies.

Beginning by showing a chart of the Giants among the thinkers of the ages from the Greek era to the present time, the lecturer took Descartes as his starting-point, explaining the significance of co-ordinates in fixing position. The relativity of motion was discussed with reference to the earth's axial, orbital and space velocity with the Solar System. Time was explained by means of a model earth, moon, sun, showing clearly the difference between the solar and the stellar day and the need for "mean" time. A tribute was paid to the sagacity of George III, who, realizing the need of the navigator as regards the determination of his position at sea to at least 30 miles, furthered the efforts of John Harrison, inventor of the Chronometer.

Tidal effects were next explained, the frictional retardation of the earth decreasing the period of rotation by 1/1000 second per century. The power involved is 2,100 million h.p. This was contrasted with Canada's developed water power of about 5 million h.p. and the maximum resources estimated at 18 million h.p. Looking into the past more than 10^9 years, the moon was probably 4,000 miles away and the day was 5 hours long. Looking into the future, day will become equal to month each being 47 present days. Solar tidal effects may then cause the moon to approach the earth.

The plasticity of the earth was discussed with special reference to the researches of Dr. F. D. Adams on the deformation of marble under pressure. Hence rotation produces an equatorial bulge, and this gives rise to the precession of the Pole and of the equinoxes. The further motion of the Pole due to the motion of the moon in an orbit inclined 5° to the plane of the ecliptic is known as Nutation and was discovered by Bradley together with the aberration of light.

In conclusion the lecturer suspended a gyroscope by a long torsion wire, and the antics of the top demonstrated the laws of motion of rotating bodies subject to disturbing forces.

A vote of thanks was moved by Dr. Ami, President of the Ottawa Centre, R.A.S.C.

The chairman called attention to the brilliance of Venus in the early morning sky, and to the comet expected to be visible to the naked eye soon after sunset about December 22. The meeting then adjourned.

A. VIBERT DOUGLAS.
Secretary.

AT TORONTO

The regular meeting of the Royal Astronomical Society of Canada was held in the Physics Building of the University of Toronto on Tuesday, May 8, at 8 p.m., Mr. Hunter in the chair.

The Minutes of the meeting of April 24th were read and confirmed. Mr. Paul Bigger, 24 Undercliffe Ave., Hamilton, Ont., was nominated for Membership, and as this was the last indoor meeting of the season it was proposed and seconded that the formality of two weeks' delay be dispensed with and the nominee be declared elected. Carried.

Mr. Hunter referred to the ether drift and the nature of ether; also the development of seismology which shows the nature of matter at the other end of the scale.

The speaker of the evening was Mr. William Gore, C.E., on the subject "Astronomy in the Life of an Engineer." It was pointed out that Astronomy and Engineering had much in common. They came together in problems relating to space, time and tides. The great and recent advances in our knowledge of the universe, as a whole, were made possible by the collaboration of the astronomer and the engineer. The great instruments used by the astronomer were essentially engineering structures. While astronomers and engineers in general adopted the same use of instruments and mathematics to the similar purposes of space measurement, the former dealing with the universe, as a whole, appealed most to our ethical and philosophical outlook, while the latter dealing with measurements and conditions close at hand administered to our simple needs.

A number of lantern slides were shown, of interest in both Astronomy and Engineering, and relating to space, time and tides. It was pointed out that in all probability the Great Pyramid, a work demanding considerable engineering ability, besides being a tomb, also acted by its shadows and reflections from its original polished casing as a sundial of the day and the year, and of considerable importance to an agricultural people having difficulties with its calendar.

Examples of the tides of the ocean were shown, and their relation to the movements of the earth, sun and moon indicated. Of special interest was a diagram showing the measured tidal variations at Toronto in Lake Ontario which amounted at Spring Tides to about one inch. The rise of these tides was shown to be much quicker than the fall, and the high tides followed the moon's meridian passage at Toronto by an average of 2½ hours.

In conclusion the problem of logging the earth in its motion through the ether was traversed as something of an engineering problem. The use of the Michelson interferometer by Professor Dayton Millar and others for this purpose

appeared to be a similar problem to that of an engineer measuring the speed of a railway coach having a few windows open, by measuring the velocity of the air in the coach. Bearing this in mind the more recent observations of Professor Millar at Mount Wilson of a drift of 10 kilometers per second in a certain direction appeared to indicate that the slip was at least 95 per cent. of the whole, and that although Einstein's Theory appeared to demand no measurable drift, yet owing to the extreme generality of the theory a difference to the measurements of those physical effects which have been anticipated by Einstein.

The Meeting was adjourned.

E. A. J. KENNEDY,
Recorder.

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